Applications of the Perten SKCS 4100 in Flour-milling

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Applications du système Perten SKCS 4100 dans la mouture de la farine

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(Texte d'une communication faite à l'occasion de la 10e conférence et exposition annuelle de l'*Association of Operative Millers*, Section du Moyen-Orient et de l'Afrique de l'Est, à Nairobi au Kenya, en novembre 1998)

RÉSUMÉ

Le système Perten SKCS de caractérisation d'un seul grain de modèle 4100 constitue un ajout important aux outils utilisés pour évaluer la qualité du blé et de la farine. Cet appareil mesure la texture des grains en broyant les grains un à la fois, en enregistrant la force exigée pour broyer le grain, et en calculant la force moyenne exigée pour broyer 300 grains, en termes d'indice de dureté. Les valeurs d'indice de récolte augmentent en fonction de la dureté accrue du grain. Le système SKCS-4100 peut faire l'analyse dans environ 3 minutes, et donne simultanément l'écart moyen et standard pour le poids du grain, le diamètre, et la teneur en eau, aussi bien que l'indice de dureté.

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Introduction:

The Perten Single Kernel Characterization System (SKCS) Model 41000 is an important introduction to the tools employed in evaluating wheat and flour quality. This device measures kernel texture by crushing the kernels one at a time, recording the force required to crush the kernel, and reporting the average force for crushing 300 kernels, in terms of a hardness index (HI). Harvest Index values increase with increasing kernel hardness. The SKCS-4100 can complete a test in about 3 minutes, and simultaneously reports mean and standard deviation data for kernel weight, diameter, and moisture content, as well as the HI.

What is kernel texture, and how does it influence wheat quality?

Wheat kernel texture is the degree of hardness or softness of the kernel. Hardness is defined as "Difficult to penetrate, or reduce to smaller fragments". Softness is the opposite of hardness.

What is wheat "Quality"?

"Wheat quality", or functionality, is the suitability of the wheat for the manufacture of the products for which it is to be purchased. To the miller another dimension must be added - the yield of flour of the quality for which clients purchase it from the mill. Wheat processing quality is mainly affected by four factors, summarized in Table 1:

Table 1. Factors involved in wheat processing quality.

Kernel texture is the main factor which enables wheat to be classified into different types, such as Hard Red (Spring or Winter), Soft White, etc. Its primary effects in milling are to influence the power required to grind the wheat (which in turn affects mechanical damage to the starch granules), and to influence the degree to which water should be added during tempering. Kernel texture is one of the two fundamental pieces of knowledge which millers should possess before tempering, the other being the moisture content of the wheat as received.

Kernel texture is actually the more important of the two, since both hard and soft wheats can be of the same moisture content at the time of arrival at the mill, but they require significantly different amounts of water to achieve efficient temper. In general, hard wheats are usually tempered to about 16.0 - 16.5 % moisture, and soft wheats to 14.5 - 15.0 %. The texture information is particularly important if economics dictate that a new class or type of wheat is to be purchased, or if more than one type of wheat is to be blended before tempering, since the kernel texture may not conform to "classical" hard or soft categories.

Kernel texture is very strongly heritable in wheat[1]. In other words hard wheat will always be hard, and soft wheat will always be soft, no matter where or when it is grown. If a series of wheat varieties of different hardness are grown in different locations and/or different seasons they will retain their order of hardness with minor changes. These differences in kernel texture have been noticed for over 100 years, mainly because earlier workers found that bread of the best appeal could be baked from flours milled from hard wheats. Several methods have been developed for texture measurement in wheat. The most important of these are summarized in Table 2.

Table 2. History of kernel texture measurement.

Table 3, illustrates the relationship between different methods of expressing kernel texture. Most methods are influenced to a greater or lesser degree by wheat moisture content. The grinding-time method is the most, and methods involving the Cyclone grinder are the least affected by wheat moisture content. The most reliable results are obtained by any method when wheat moisture content lies between 10.5 - 12.5 %.

Table 3. Methods of expressing wheat kernel texture.

Kernel texture can be tested most rapidly using **Near-InfraRed** (NIR) technology, which is applicable to both ground and intact kernels[2,3]. The most practicable reference methods include the Particle Size Index (PSI) methods, using either a burr mill, or the U-D Cyclone impeller mill. This involves grinding a sample, and sieving a weighed amount (usually 10g) through a standard screen for a standard time. The percentage of throughs are recorded as the PSI. Since soft wheats are more easily pulverized than hard wheats they release more fine material on sieving, and PSI values decrease in wheat types with harder kernels (whereas HI values increase). Table 4 summarizes the range in kernel texture among the common wheats of commerce, together with a proposed classification, in terms of both HI and PSI.

Table 4. Classification of wheat by kernel texture.

Calibration of the SKCS 4100.

The original HI calibration of the SCKS 4100 was based on the NIR method of the USDA Research Center at Beltsville, MD[4]. The instrument was calibrated using a set of 10 samples of wheat (5 hard and 5 soft), with arbitrary values of respectively 75 and 25, as defined by the USDA NIR method. An alternative calibration has recently been added, which enables the SKCS 4100 to record kernel texture in units of PSI (U-D Cyclone-ground), as well as HI. This also permits the operator to compare SKCS results to the reference method for PSI (Approved Method No. 55-30 of the American Association of Cereal Chemists). This is a very useful method for verification of the SKCS texture values.

Relationship of SKCS data to flour quality factors.

Table 5 summarizes the relationship of SKCS kernel texture data to the flour quality parameters commonly associated with kernel texture:

Table 5. Relationship of wheat kernel texture to some flour quality parameters.

Starch damage, gas production and water absorption all increase with increasing kernel hardness. This is related to differences in energy involved in grinding the wheat into flour, and is directly related to the production of damaged starch during milling. Table 6 gives the inter-correlations between kernel texture as measured by PSI and associated flour factors. These relationships were all determined in flour milled from sound wheat. Starch-related factors are strongly influenced by the presence of excessive α-amylase. Starch damage may decrease slightly, due to a small reduction in hardness caused by adverse weather conditions during the harvest period, which induce sprouting. Flour water-absorption is also likely to decrease slightly. Gas production will be increased, due to the effect of the α-amylase on the sound, as well as the mechanically-damaged starch granules.

Table 6. Inter-relationships between wheat kernel texture and some associated parameters.

The relationship between wheat protein content and kernel texture is peculiar, in that wheats of different texture are affected differently by protein content. Protein content affects durum and soft wheat classes by

inducing small increases in hardness, as protein content increases. With wheat of the Hard Red Spring class, and wheat of similar kernel texture, protein content has the opposite effect, and the wheat becomes significantly softer as protein content increases. Table 7 illustrates this. The data were compiled over a 5-year period from wheat samples representing composites of harvest surveys, and cargoes of Canadian CWRS wheat.

Table 7. Influence of protein content on texture of CWRS wheat kernels.

Kernel texture and milling potential.

Kernel texture influences power consumption during milling. Hard wheat requires more power to grind the wheat than does soft wheat, and power consumption can increase by as much as 30 % when milling hard, relative to soft wheat. On the other hand, the endosperm of hard wheat is cellular, and flour particles consist mainly of clumps of cells. The cell-structure of the endosperm of soft wheat often ruptures during maturation of the wheat in the field, and the cellular nature of soft wheat flour is not so well-defined. As a result, hard wheat flours and stocks are easier to bolt than are those of soft wheats. Other factors affected by kernel texture include break flour release, and overall flour yield.

Table 8 summarizes the results of milling a series of wheats of widely-different kernel texture on a Buhler ML-202 laboratory flour mill. All wheats were tempered to optimum. Each PSI value is the mean of up to 26 samples of the same wheat variety grown in replicated trials at different locations and seasons. An interesting point is the overall correlation between PSI and the individual correlations between PSI and flour yield (column 4 of Table 8). This shows that for very hard to hard wheat, flour yield increases as the wheat becomes softer within its class. The reverse was true for soft wheats, where flour yield improved as these wheats became harder within the class. There was little or no correlation between PSI and the correlation between PSI and flour yield for wheat of intermediate hardness, which corresponds to CWRS and APH wheat types.

Table 8. Influence of wheat kernel texture on milling performance

Kernel texture and tempering.

Millers have long-since recognized the need to temper hard wheat to higher levels of moisture content than soft wheat. The SKCS 4100 can assist with tempering in three ways. It provides a measure of kernel texture, and an accurate result for moisture content, both of which are essential guidelines as to water addition. It can also be used to monitor the degree to which the water added during tempering has become evenly distributed throughout the wheat. This is particularly useful when the mill is preparing to mill wheat of very low moisture content, since tempering has to be carried out in two (sometimes even three) stages. The instrument provides information on the standard deviation (SD) of all four of the factors in the 300 kernels that it measures, as well as the average result. The SD shows the variability among the kernels. The SD of moisture content is very high if the measurement is taken soon (within the hour) after addition of tempering water. By comparing the SD at different intervals following water addition with the SD of the wheat before tempering the miller can determine accurately when the water has become evenly distributed among all of the kernels.

Tables 9 and 10 show the changes in apparent kernel weight, diameter, texture and water content of several types of Canadian wheat, together with changes in the respective standard deviation data. The SKCS kernel texture is reported in terms of PSI units, since the PSI test was used to verify the kernel texture before tempering, and after the tempering period.

Table 9. Influence of time after tempering on SKCS-4100 values for CWRS wheat.

Table 9 shows the influence of time after addition of tempering water on the four kernel parameters, and their respective SD values. Kernel weight and diameter increased slightly due to the addition of water (as may be expected), but did not change significantly during the tempering period. This was observed for all wheat classes studied. The influence of water near the surface of the kernels early in the tempering stage was to cause significant reduction in the apparent texture of the kernels. The PSI values increased, and HI values decreased as tempering time (time after water addition) progressed, until the kernel texture at 16 hours was similar to the original figure. This is illustrated in Figure 1 for Canada Prairie Spring (White) wheat, which compares the respective differences in HI and PSI values for White CPS wheat during two-stage tempering..

Figure 1. Changes in apparent kernel texture of Canada Prairie Spring wheat after addition of water.

A. Changes in apparent HI
B. Changes in apparent PSI

Standard deviation of the PSI values for freshly-tempered wheat increased significantly at the first hour after tempering, then fell to a value slightly lower than the original value after 16 hours. Moisture values also fell from an apparent early high level to stable values after 16 hours. The SD values dropped dramatically during the first 8 hours after tempering, and stabilized 16 hours after the addition of the tempering water.

Table 10 gives data for five Canadian wheat types. Data for thousand kernel weight and diameter followed the same pattern as CWRS wheat, in that after an early increase on the addition of water, there were no significant changes. Data for kernel texture (PSI) and moisture contents also followed the same trends as for CWRS wheat. In all cases apparent PSI increased during the 24 hour tempering period, while the standard deviation data indicated little change after 16 hours. Moisture content fell to stable levels after 8 - 16 hours, as indicated both by the observed moisture contents, and their standard deviations.

Table 11 summarizes data obtained by tempering dry wheat from about 7.5 % moisture to about 16 % moisture in two stages. The wheat was air-dried to 7.5 % moisture, and water was added to bring the moisture content up to about 12 % in the first stage. The second stage involved addition of water to bring the final moisture content up to about 16 %. Figure 2 illustrates the changes in SKCS values for moisture content of CWRS wheat at different intervals following the addition of tempering water.

Figure 2. Changes in SKCS-4100 moisture values following addition of tempering water to CWRS wheat

Kernel texture data increased and standard deviation data decreased in both stages in a manner similar to that observed in the earlier single-stage tempering study. For both wheat types both apparent moisture levels and standard deviations fell much more rapidly during the first, than in the second tempering stage. For practical purposes based on these data, the second addition of water could likely be made 12-16 hours after the first water addition.

Conclusions.

1. The SKCS 4100 Single Kernel Characterization System provides a rapid and accurate method for measuring wheat kernel texture and moisture content, both of which are necessary to efficient tempering.

2. The standard deviation of the moisture content of tempered wheat relative to that of the original wheat provides a useful indication of the degree to which moisture has become uniformly distributed in the wheat as a result of tempering. This can be particularly useful in determining time of second addition of water during two-stage tempering.

References:

1. Symes, K.J. 1965. Aust. J. Agric. Res. 16: 113 - 123.

2. Saurer, W. 1978. Getreide, Mehl u. Brot 32: 272 - 276.

3. Williams, P.C. 1991. Cereal Chem. 68: 112-114.

4. Delwiche, S., and Norris, K.H. 1993. Cereal Chem. 70: 29-35.

Table 1. Factors involved in Wheat Quality.

Factor	Contribution to processing and end-product quality
Kernel Color	Flour and crumb color
Kernel texture (hardness/softness)	Tempering (milling); starch damage; gas production; water absorption
Gluten strength	Mixing tolerance; gas retention; bread, cooked pasta and noodle texture
Gluten (protein) content	Wheat price; mixing tolerance, gas retention; bread, cooked pasta and noodle texture

Table 2. History of Wheat Kernel Texture Measurement

Name	Date	Principle	Reference
N.A. Cobb	1896	"Biting" - force to crush	Agric. Gazette, NSW 7: 279
G.H. Cutler *et al*	1935	Granularity (Particle Size Index	Cereal Chem. 12: 129
C.J. Chung *et al*	1972	Pearling	J. Korean Soc. Agric. Eng. 14: 9
F.G. Kosmolak	1978	Grinding Time	Can. J. Plant Sci. 58: 415
W. Saurer	1978	Near-infrared Spectroscopy	Getreide Mehl u. Brot 32: 272
W.R. Windham *et al*	1993	SKCS 4100 force to crush	Cereal Chem. 70: 662

Table 3. Methods of expressing wheat kernel texture.

Method	Durum	CWRS/DNS*** APH/AH	CPSR/W ASW	SWW/ /SRW
PSI Burr-mill ground	6 - 10 %	14 - 18	21 - 26	30 - 38
PSI Cyclone-ground	32 - 42 %	49 - 55	56 - 62	68 - 77
Grinding-time (Burr-mill)	40 - 48 Sec	45 - 55	55 - 65	80 - 220
Pearling Index	40 - 50	40 - 50	55 - 65	65 - 75
NIR* Cyclone-ground	32 - 42	49 - 55	56 - 62	68 - 77
SKCS Hardness Index	85 - 105	75 - 90	45 - 60	5 - 35**

* NIR = Near-infrared: ** Negative data can be obtained for some soft wheats.
*** CWRS = Canada Western Red Spring; DNS = Dark Northern Spring; APH = APH = Australian Prime Hard; AH = Australian Hard; CPSR /W = Canada Prairie Spring Red /White; ASW = Australian Standard White; SWW/SRW = Soft White Winter/Soft Red Winter.

Table 4. Classification of wheat types according to kernel texture.

Proposed Classification	PSI* KT-3303	PSI U-D Cyclone	Perten SKCS HI	Wheat Type
Extra hard	Up to 7	Up to 35	90 - 100+	Durum, other tetraploid wheats
Very Hard	8 - 11	36 - 44	80 - 89	Durum, some white wheats
Hard	12 - 15	45 - 55	65 - 79	CWES; CWRS; DNS; HRW; APH; AH; Others
Medium Hard	16 - 20	56 - 62	50 - 64	CWRW; CPSR; AH; ASW; Others
Medium Soft	21 - 25	63 - 66	40 - 49	Some CPSW; SRS; Some ASW; Others
Soft	26 - 30	67 - 70	30 - 39	Some ASW; CWSWS; Some Club, Others
Very Soft	31 - 36	71 - 75	15 - 29	Some CWSWS; Club, SWW; SRW; AS; Others
Extra Soft	37 +	76 +	Up to 14**	SWW; SRW; Some AS; Others

* PSI = Particle Size Index; HI = Hardness Index; CWES = Canada Western Extra Strong; CWRS = Canada Western Red Spring; DNS = Dark Northern Spring (U.S.); HRW = Hard Red Winter: APH = Australian Prime Hard; AH = Australian Hard; CPSR = Canada Prairie Spring (Red); CPSW = Canada Prairie Spring (White); ASW = Australian Standard White; SRS = Soft Red Spring; CWSWS = Canada Western Soft White Spring; SRW = Soft Red Winter; SWW =- Soft White Winter; AS = Australian Soft.

** HI data may be negative for some extra soft wheat samples.

Table 5. Relationship of wheat kernel texture to some flour quality factors

SKCS PSI Cyclone	SKCS HI	Starch Damage Megazyme	Water Absorption*	Gas Production 6-Hour	Gas Production Hourly increments
Up to 35	90 - 100+	9 - 11	68 - 72	500+	90
36 - 44	80 - 89	9 - 11	68 - 72	500+	90
45 - 55	65 - 79	8 - 10	64 - 67	450 - 500	80
56 - 62	50 - 64	5.5 - 7	59 - 65	350 - 450	65
63 - 66	40 - 49	4 - 6	58 - 61	250 - 300	50
67 - 70	30 - 39	2 - 3.5	52 - 57	100 - 250	45
71 - 75	15 - 29	2 - 3	50 - 53	100 - 150	40**
76 +	Up to 14	2 - 3	48 - 51	100 - 150	Up to 30**

* Farinograph water absorption;

Table 6. Inter-relationships between kernel texture and associated factors:

Quality factor	PSI*	Protein Content	Starch Damage	Gas Production
Protein content	- 0.44	-	-	-
Starch damage (Megazyme)	- 0.91	0.54	-	-
Gas Production (6 Hour)	- 0.79	0.37	0.81	-
Water absorption	- 0.88	0.73	0.78	0.61

* PSI = Particle Size Index (Cyclone - ground)

Table 7. Influence of wheat protein content on kernel texture and starch damage in CWRS wheat

Wheat Protein Content %	PSI	Starch Damage (Megazyme)
11	49.8	8.0
12	51.4	7.4
13	52.9	6.9
14	54.5	6.4
15	56.0	5.9

Table 8. Influence of kernel texture on milling performance

PSI Cyclone-ground	Break flour Release %	Extraction %	r: PSI/Extraction
37	23	62	0.71**
40	27	67	0.69
48	35	71.9	0.56
56	41	75.6	- 0.03
61	52	70.1	- 0.33
71	70	70.1	- 0.27
74	82	67.5	- 0.63
77	112	70.8	- 0.45

** All data obtained from Buhler ML-202 - milled wheat; r: (PSI/r:PSI/Extraction) = 0.954

Table 9. Influence of time after tempering on SKCS-4100 values for CWRS wheat

Parameter		0 (As is)*	1 hr.	2 hr.	4 hr.	8 hr.	16 hr.	24 hr.
TKW ** Mean		30.8	32.3	32.4	32.6	31.8	31.5	32.5
	SD	8.9	9.5	9.7	9.1	8.6	8.8	9.3
Diameter	Mean	2.36	2.40	2.40	2.42	2.37	2.38	2.40
	SD	0.54	0.52	0.55	0.57	0.52	0.52	0.52
PSI	Mean	50.2	37.5	43.8	48.5	51.0	52.0	52.3
	SD	6.47	7.52	7.10	6.88	6.62	6.30	6.15
Moisture	Mean	12.2	16.5	16.2	15.9	15.7	15.7	15.7
	SD	0.40	0.72	0.82	0.64	0.47	0.40	0.38

* Before addition of tempering water

** TKW = thousand kernel weight (g); SD = standard deviation; PSI = particle size index; SD = Standard Deviation.

Table 10. Influence of time after tempering on SKCS-4100 value for apparent kernel texture, and moisture content for some Canadian wheat classes.

Wheat type	Parameter		0 (As is)*	1hr.	2 hr.	4 hr.	8 hr.	16 hr.	24 hr.
Grade 2CWRS**	PSI	Mean	51.7	42.6	47.0	50.0	51.3	52.4	53.4
		SD	6.52	7.80	7.53	6.42	6.18	6.40	6.06
	Moisture	Mean	11.8	16.7	15.9	15.5	15.3	15.3	15.4
		SD	0.40	0.71	0.54	0.53	0.43	0.33	0.36
CWES	PSI	Mean	46.7	40.4	45.6	48.2	49.7	49.6	51.2
		SD	7.31	9.18	8.14	7.70	7.62	7.04	7.18
	Moisture	Mean	12.4	16.4	15.8	15.5	15.4	15.5	15.5
		SD	0.44	0.62	0.55	0.52	0.44	0.40	0.36
CPS White	PSI Mean		59.4	55.2	57.1	56.4	57.1	58.0	58.5
		SD	8.92	8.51	8.26	8.02	8.23	8.07	7.86
	Moisture	Mean	12.9	15.4	15.2	15.0	14.9	14.9	14.9
		SD	0.49	0.51	0.44	0.42	0.39	0.39	0.36
CWSWS	PSI Mean		67.8	-***	63.1	64.2	65.6	67.2	67.7
		SD	4.97	-	5.55	5.11	4.94	4.82	4.90
	Moisture	Mean	12.02	-	16.0	15.6	15.0	14.9	15.0
		SD	0.45	-	0.76	0.69	0.62	0.52	0.46
CWAD	PSI	Mean		-	33.9	35.0	38.8	39.5	40.5
		SD		-	10.48	9.84	9.41	9.34	8.30
	Moisture	Mean		-	16.4	16.3	16.1	16.1	16.2
		SD		-	0.59	0.54	0.48	0.42	0.40

* Before addition of tempering water

** CWRS = Canada Western Red Spring; CWES = Canada Western Extra Strong; CPS = Canada Prairie Spring; CWSWS = Canada Western Soft White Spring; CWAD = Canada Western Amber Durum

*** SKCS would not process at only 1 hour after addition of tempering water.

Table 11. Influence of time after tempering on SKCS values for apparent kernel texture and moisture content for two-stage tempering of two Canadian wheat types.

Wheat type		Parameter		0 (As is)*	1 hr.	2 hr.	4 hr.	8 hr.	16 hr.	24 hr.
CWRS	Stage I	PSI	Mean	49.6	32.6	37.8	44.0	45.6	48.0	48.4
			SD	6.11	7.32	7.44	7.18	6.48	6.18	6.16
		Moisture	Mean	7.5	15.4	15.0	13.6	12.9	12.6	12.5
			SD	0.48	1.00	0.87	0.65	0.50	0.40	0.41
CWRS	Stage II	PSI	Mean	48.4	36.4	40.2	43.7	48.0	49.7	50.4
			SD	6.16	7.29	7.24	6.44	5.76	5.78	5.67
		Moisture	Mean	12.5	16.9	16.3	15.8	15.6	15.5	15.7
			SD	0.41	0.70	0.70	0.54	0.42	0.36	0.38
CPS White	Stage I	PSI	Mean	56.6	42.8	52.1	56.8	57.5	58.2	57.6
			SD	7.54	9.77	8.8	7.84	7.94	6.90	6.86
		Moisture	Mean	7.5	16.0	14.6	13.3	12.6	12.3	12.3
			SD	0.42	0.93	0.92	0.66	0.56	0.44	0.42
CPS White	Stage II	PSI	Mean	57.6	53.8	55.8	57.2	58.0	57.5	57.6
			SD	6.86	8.20	7.53	7.28	7.00	6.70	6.75
		Moisture	Mean	12.3	15.9	15.5	15.2	15.0	14.9	14.9
			SD	0.42	0.72	0.64	0.50	0.42	0.37	0.39

* Before addition of tempering water.